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VIRGINIA SALTWATER RECREATIONAL FISHING DEVELOPMENT FUND
SUMMARY PROJECT APPLICATION*

NAME AND ADDRESS OF APPLICANT:

Old Dominion University Research Foundation
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PROJECT LEADER (name, phone, e-mail):

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PRIORITY AREA OF CONCERN:

Research and Data Collection

PROJECT LOCATION:

Throughout Chesapeake Bay

DESCRIPTIVE TITLE OF PROJECT:

Trophic position and ecological function of juvenile menhaden in Chesapeake Bay

PROJECT SUMMARY:

This proposed research seeks to address a critical gap in our knowledge of the ecosystem services provided by juvenile menhaden in Chesapeake Bay. Specifically, we are going to measure isotope signatures of menhaden and its prey. This will allow us to determine the nutrients menhaden are exporting to sport fishes in Chesapeake Bay. This represents a link in the Chesapeake Bay food web that must be fully considered to move the management to an ecosystem based management philosophy. Current management practices do not consider multi-species interactions which is a key component of ecosystem based management.

EXPECTED BENEFITS:

Menhaden are a key component of the diet of many sport fishes in Chesapeake Bay. As such, management of this resource must consider all aspects of harvest. Therefore, knowledge of the ecosystem services menhaden provide in Chesapeake Bay is critical. This research will answer address one such gap in our knowledge. We will explicitly trace energy flows to menhaden in Chesapeake Bay. This will provide data to managers in state and federal agencies to use in ecosystem based management models that fully consider the role juvenile menhaden play in the ecosystem.

COSTS:

VMRC Funding:	$43,967
Recipient Funding:	$ 7,293
Total Costs:	**$51,260**

Detailed budget must be included with proposal.

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*This form alone does not constitute a complete application, see application instructions or contact Sonya Davis at 757-247-8155 or sonya.davis@mrc.virginia.gov

1) Analyze stomach contents
2) Complete all statistical analyses
3) Draft manuscripts/ final report

Budget

Salary	$19,950
Fringe Benefits	$6,224
Total	$26,174
Supplies	$1,000
General	$8,000
Travel	$1,500
Total Direct	$36,674
Indirect	$7,293
Total	$43,967

Budget Justification

Salary
1) No salary support for PI Dr. Cynthia M. Jones.
2) Six months of salary support is requested for Co-PI Dr. Jason J. Schaffler. This is to cover time for field work (collection of POM samples and menhaden in the lower Chesapeake Bay), processing samples (including preparation of muscle tissue and POM samples for isotope ratio measurements and stomach content analysis), statistical analyses and completion of manuscripts and reports.

Supplies
1) We request $500 for glass fiber filters which are required to collect POM from water column samples. Also included in this are containers to collect water samples.
2) We request $300 for scintillation vials which are used to freeze dry muscle tissue and POM samples.
3) We request $200 to cover miscellaneous supplies such as slides, zip lock bags, sharpies, etc.

General
1) We request $500 to cover costs associated with publishing peer reviewed manuscripts.
2) We request $7,500 for muscle and POM isotope analyses. Cornell University Stable Isotope Lab charges $15 per sample for carbon and nitrogen isotope analyses. We expect to analyze 15 fish samples per time period. We will collect fish from 3 time periods and 8 drainages in Chesapeake Bay. This will result in 360 muscle isotope samples at a cost of approximately $5,500. University of California at Davis charges $9 per sample for carbon and nitrogen isotope analysis. We expect to analyze 9 POM

samples per time period across 3 time periods and 8 drainages. This will result in 216 POM at a cost of approximately $2,000.

Travel
1) We request $500 to cover travel expenses to attend 1 scientific meeting to present the results of this research.
2) We request $1,000 to cover travel expenses to collect POM and menhaden samples. This involves travel to Maryland DNR headquarters in Annapolis, Md or travel to VIMS at Gloucester Point, VA.

Indirect Costs
1) Indirect costs are billed at a rate of 25% for a total of $7,293. However, ODU has an allowable indirect cost rate of 50%. Therefore, ODU will contribute this difference which is an additional $7,293.

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Trophic position and ecological function of juvenile menhaden in Chesapeake Bay

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Summary

Throughout much of the recreational angling community there have been calls for the cessation of industrial fishing practices directed at Atlantic menhaden. This is due in large part to the ecological benefits ascribed to juvenile menhaden. However, stock assessment reports for Atlantic menhaden indicate overfishing is not occurring and the stock is not overfished. From a management perspective this may be true, but management does not take into account the ecosystem services (forage for striped bass, bluefish, weakfish, etc.; plankton consumption; nutrient sequestration) that an abundant juvenile and adult menhaden population provides. This proposed research seeks to address this very problem. What are the ecosystem services that juvenile menhaden are providing to the Chesapeake Bay ecosystem? This question is best answered in quantifying the energy (i.e. nutrients responsible for growth) juvenile menhaden are moving from their nursery habitats to the many predatory sport fishes that depend upon them for much of their nutrition. This proposed research will determine what basal resources (i.e. algal production, terrestrial production, etc.) are driving menhaden growth and thus determining the ecosystem services menhaden provide in Chesapeake Bay.

Statement of Problem

Atlantic menhaden *Brevoortia tyrannus* is an estuarine-dependent clupeid that ranges from Nova Scotia to central Florida (Ahrenholz 1991). Menhaden fill an important ecological niche as a filter feeder and prey species in Chesapeake Bay and support an important commercial fishery in the Mid- and South-Atlantic Bights (Dryfoos et al. 1973; Gottlieb 1998; Coleman et al. 2004). Currently, there are concerns over the standing stock and recent low levels of recruitment in the menhaden population in the Mid-Atlantic Bight (ASMFC 2004) and evidence of localized depletion in portions of Chesapeake Bay has led to additional concerns over whether current levels of menhaden recruitment can sustain piscivores at their current population sizes (Uphoff 2003; Hartman and Margraf 2003).

Adult menhaden spawn over a protracted season lasting from late fall through early spring (Higham and Nicholson 1964; Warlen 1994). Spawning typically takes place in nearshore waters over the continental shelf from Rhode Island to South Carolina (Stegmann et al. 1999). Eggs and larvae are transported by meteorologic and oceanographic processes to estuarine nursery areas along the Atlantic coast (Nelson et al. 1977; Pietrafesa and Janowitz 1988; Quinlan et al. 1999). In each of these nursery areas, juvenile menhaden arrive primarily through passive transport mechanisms from a single source population which prevents any genetic or morphological structuring of the population. Juvenile menhaden nursery grounds are highly correlated with areas of high phytoplankton biomass primarily due to their obligate filter-feeding lifestyle (Friedland et al. 1989).

Chesapeake Bay is a large and complex estuary fed by several major rivers that result in spatially isolated areas of high phytoplankton production and biomass (Roman et al. 2005) where juvenile menhaden reside throughout the summer (Friedland et al. 1996). Chesapeake Bay and its sub-estuaries are thought to contribute approximately 70% of the total recruits to the coast wide menhaden population (Ahrenholz et al. 1989). However, this figure alone is not a true representation of the menhaden dynamics within Chesapeake Bay. Because of the spatially isolated nature of optimal menhaden nursery areas within the Bay, it is likely that there are differences in the ecological processes operating in each of these areas that structure the subsequent recruits to the coastal migratory population. These potential differences in relative value of estuarine nursery areas can lead to dramatic fluctuations in year class success (Ross 2003).

In Chesapeake Bay, inter-annual variations in rainfall and river flow mediate nutrient inputs and result in extreme variations in zooplankton and phytoplankton productivity and biomass (Roman et al. 2005). Survival and growth can vary based on the spatially and temporally explicit environmental conditions into which young recruits initially settle (Peterson et al. 2004). Therefore, the likelihood of encountering different environmental conditions in the different menhaden nursery areas of Chesapeake Bay is high. This result alone raises several questions about our knowledge of menhaden recruitment dynamics in Chesapeake Bay and demonstrates the need for the type of research proposed here.

Muscle carbon and nitrogen stable isotope ratios are one means of assessing trophic relationships between consumers and their prey sources (Peterson and Fry 1987, Post 2002). A combination of stable isotope and stomach content analyses have been successfully used to link predators to their prey species and identify the basal energy source driving these systems as algal or macrophyte (Bode et al. 2004, Thresher et al. 1992, Hart and Lovorn 2003).

There are increasing calls for ecosystem based management (EBM) in Chesapeake Bay and elsewhere. One form of EBM is ecological network analysis (ENA). ENA is a modeling technique for examining the structure and flow of material in ecosystems (Wulf et al. 1989, Fath and Patten 1999, Dame and Christian 2008). ENA incorporates a suite of analyses that include input–output analysis, trophic structure analysis, pathway analysis, biogeochemical cycle analysis, and information analysis. Quantifying the role of menhaden in Chesapeake Bay remains a fundamental step to managing the fisheries of Chesapeake Bay from an ecological perspective.

Background

There have been multiple studies that have examined the diet of menhaden (June 1971, Jeffries 1975, Lewis and Peters 1984, Lewis and Peters 1994). Most studies have found that juvenile menhaden consume a variable mixture of phytoplankton, zooplankton and detritus. The ratio appears to be controlled by the relative abundance in the environment, although no studies have confirmed this. As such, juvenile menhaden are consuming mostly detritus and phytoplankton or particulate organic matter (POM) in the environment. The gill raker feeding apparatus has been examined throughout ontogeny (Friedland et al. 2006). These findings indicate that the sieving apparatus of juvenile menhaden are optimized for particles <10-12 µm. This size information

and the diet information further supports the hypothesis that menhaden indiscriminately consume any optimal sized particle in the environment.

We know from research conducted at ODU that menhaden are summer long residents in the sub-estuary they initially recruit to (Schaffler et al. In Prep). Therefore, the nutrients they will eventually export in the form of menhaden biomass from each of these systems are directly related to production in these systems. Another consequence of maintaining residence in a sub-estuary of Chesapeake Bay is that unique isotope ratios could be conferred to the menhaden in these systems. This is a likely explanation for the carbon and nitrogen isotope ratios observed in menhaden and striped bass in other RFAB funded research (Schaffler et al. In Prep). This proposed research builds on previous questions and will allow us to begin constructing more detailed ENAs involving striped bass – menhaden dynamics.

Significance

Traditional fisheries management has emphasized benefits to humans of the harvested resource in terms of revenue, employment, recreation and tradition. However, from an ecosystem perspective these goals need to be broadened to include health and sustainability (Lubchenco et al. 1991, National Research Council 1999). As we move from single species management to EBM there we must first develop an understanding of the basic characteristics and principles that structure the ecosystem and provide opportunities for managing human impacts.

The information gathered from this project will benefit Virginia anglers in several ways. 1) This type of information is information needed for EBM models. This will result in more detailed and accurate representations of the menhaden's role in the Chesapeake Bay ecosystem. 2) Understanding the linkages between menhaden and the environment will allow managers to make better forecasts of prey availability which will translate into better management decisions. 3) There is a lack of understanding involving menhaden-striped bass dynamics in Chesapeake Bay. Current models suggest the menhaden stock is capable of generating sufficient recruits to replace the population; however, there is concern over whether the current abundances of menhaden are providing the desired ecosystem services. This proposed research will provide answers to questions our previous research generated. That is, what is the cause of the variation in menhaden muscle isotope signatures? Additionally, this will aid in evaluating the linkages between menhaden and striped bass isotope signatures.

Objectives

This proposed research is to quantify the role of juvenile menhaden in Chesapeake Bay. Determining what nutrients menhaden are transferring to sport fish in Chesapeake Bay is a primary concern to move towards EBM. Our specific objectives are to 1) examine juvenile menhaden diet in the major drainages to Chesapeake Bay, 2) examine carbon and nitrogen stable isotope ratios in menhaden muscle tissue in the major drainages to Chesapeake Bay, 3) examine water column POM (particulate organic matter; i.e. the major constituent of menhaden diet) carbon and nitrogen stable isotope ratios in the major drainages to Chesapeake Bay, 4) determine what nutrients menhaden are extracting from the water column. With this information we will be able to accurately characterize the trophic role of juvenile menhaden in Chesapeake Bay.

Hypotheses

HO_1: Juvenile menhaden diet will not differ spatially or temporally among drainages in Chesapeake Bay.

HA_1: Juvenile menhaden diet will differ spatially or temporally among drainages in Chesapeake Bay.

HO_2: Menhaden muscle isotope ratios will not differ spatially or temporally among drainages in Chesapeake Bay.

HA_2: Menhaden muscle isotope ratios will differ spatially or temporally among drainages in Chesapeake Bay.

HO_3: Water column POM isotope ratios will not differ spatially or temporally among the major drainages in Chesapeake Bay.

HA_3: Water column POM isotope ratios will differ spatially or temporally among the major drainages in Chesapeake Bay.

HO_{4a}: Menhaden are using similar energy resources among all major drainages in Chesapeake Bay.

HA_{4a}: Menhaden are not using similar energy resources among all major drainages in Chesapeake Bay.

HO_{4b}: Menhaden muscle isotope ratios are reflected in POM isotope ratios.

HA_{4b}: Menhaden muscle isotope ratios are not reflected in POM isotope ratios.

Methods

Fish Collections

We have worked with Eric Durell (Maryland Department of Natural Resources) to collect menhaden from the Maryland portion of Chesapeake Bay for otolith chemical analyses. We will continue these collections so that we can use these fish for multiple projects. Menhaden are collected as by-catch in the juvenile striped bass seine survey. After enumeration, fish are placed on ice and transported back to the lab and frozen.

We have collected juvenile menhaden in the Virginia portion of Chesapeake Bay from multiple sources. We have collected menhaden in cast nets, in trawls from fishery independent sampling in seagrass beds, and from the VIMS juvenile trawl survey. We expect to be able to obtain samples from each of these sources.

All fish collections occur during July-September from multiple locations within each tributary. This coverage has proven to be a reliable means of characterizing the chemistry in juvenile menhaden otoliths and we expect it to also characterize the variation in muscle isotope chemistry.

Water column characterization

We will collect water samples concurrently with each fish collection. We will collect a whole water sample to count and identify potential prey items at each location and triplicate 50 ml water column filtered through glass fiber filters (GFF) to examine carbon and nitrogen isotope signatures of potential prey.

Stable isotope measurements

We will remove an approximately 2 g white dorsal muscle sample from each fish. This sample will be freeze dried and ground to a homogenous powder. A 0.5-1.0 mg subsample of homogenized powder will be analyzed for bulk carbon and nitrogen isotope values by an isotope ratio mass spectrometer (IRMS). Isotope ratio measurements will be conducted at the Cornell Isotope Lab.

Glass fiber filters will be treated similarly to muscle tissue. Each GFF will be freeze dried and ground to a homogenous powder. However, the entire sample will be analyzed for bulk carbon and nitrogen isotope values due to the lower fraction of nitrogen present in these samples. Because of the smaller quantities of nitrogen present, we will need to analyze these samples on an IRMS optimized for smaller quantities of nitrogen. Isotope ratio measurements will be conducted at the University of California at Davis Stable Isotope Lab.

Diet analyses

We will extract the anterior portion of the alimentary tract and the total volume of gut contents will be determined by water displacement in a graduated cylinder. We will then take a random sub-sample of the stomach contents for identification of individual food items. Food items will be identified to the lowest feasible taxonomic level, and volumes determined using a modified glass slide, containing a rectangular well etched with a grid. Each square on the grid represents a volume of 0.0001 ml. Total volumes of each diet item in the sub-sample will be calculated based on the total volume of gut contents for each individual (Zeung et al. 2009). Diet will be compared between tributaries and across time using multivariate analysis of variance.

Stable isotope analyses

We will analyze menhaden and water column isotope ratios with a modified multivariate analysis of variance approach that we have developed (Khattree and Naik 1999, Schaffler et al. In Review). This technique will allow us to examine directional changes in isotope ratios between tributaries and across time. Similarly, we will be able to use this same approach to examine linkages between POM and menhaden muscle isotope ratios.

To determine where production is occurring (i.e. terrestrial, algal, benthic) supporting menhaden growth, we will use an isotope mixing model that is capable of resolving up to 4 sources (Phillips and Koch 2004).

Expected Results

Fisheries Management

The results of this research will directly benefit managers at VMRC, MdDNR, and NOAA by characterizing the trophic position of menhaden in Chesapeake Bay. This information is vital to move to an ecosystem based approach for fisheries management in Chesapeake Bay. This is particularly important for describing the linkages between menhaden and striped bass.

Academic contributions

We expect to submit at least two manuscripts from this work. 1) Menhaden diet has been grossly described as percent phytoplankton, zooplankton, detritus, etc. We expect to improve on this by relating species consumed to environmental availability. This paper will thoroughly describe the diet of juvenile menhaden in Chesapeake Bay and examine both temporal and spatial variation. 2) We will show the relationship between POM and menhaden muscle isotope ratios. This is important because it will set the context for EBM in Chesapeake Bay. This will also fill a critical knowledge gap for one of Chesapeake Bay's most important fishes.

Timeline

July-September
  1) Collect menhaden – Eric Durell has committed to collecting menhaden
  2) Collect water column POM samples

October-December
  1) Process menhaden samples
       a. Measure TL, FL, SL
       b. Extract alimentary tract
       c. Remove muscle tissue
  2) Process muscle tissue
       a. Freeze dry muscle tissue
       b. Homogenize and weigh muscle tissue subsamples
  3) Process POM samples
       a. Freeze dry POM samples
       b. Homogenize POM samples
  4) Process stomach contents
January-March
  1) Continue to process stomach contents
  2) Analyze isotope ratio data
April-June

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